Investigating the location and strength of the auroral electrojets using Swarm

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1) Background

The auroral electrojets are a key space weather phenomenon. They are formed by horizontal Hall currents that flow within the ionospheric polar regions at an altitude of around 115 km. They form ovals around the magnetic poles but their latitudinal position, width, and strength are highly variable. These are governed by geomagnetic activity and solar wind conditions, along with a global ordering by the main magnetic field.

Typically, greater geomagnetic activity will cause the electrojets to intensify and move equatorward, associated with greater auroral displays but also with more severe consequences both on Earth and in space:
- Geomagnetically induced currents (GICs)
- Disturbance to radio communications and GNSS signals
- Disruption to navigation applications
- Increased drag on satellites due to expansion of the atmosphere

The auroral electrojet system can be described by the AE activity indices derived from measurements at ground-based magnetic observatories. The accuracy of the AE index is limited by the observatories' fixed positions, which inhibits the ability to consistently locate the electrojets. Significantly, the indices only cover the Northern hemisphere so do not capture the differences between the Northern and Southern systems. Polar low-Earth orbit satellite observations offer the opportunity to overcome these limitations, by providing excellent latitudinal resolution and coverage equally over both poles.

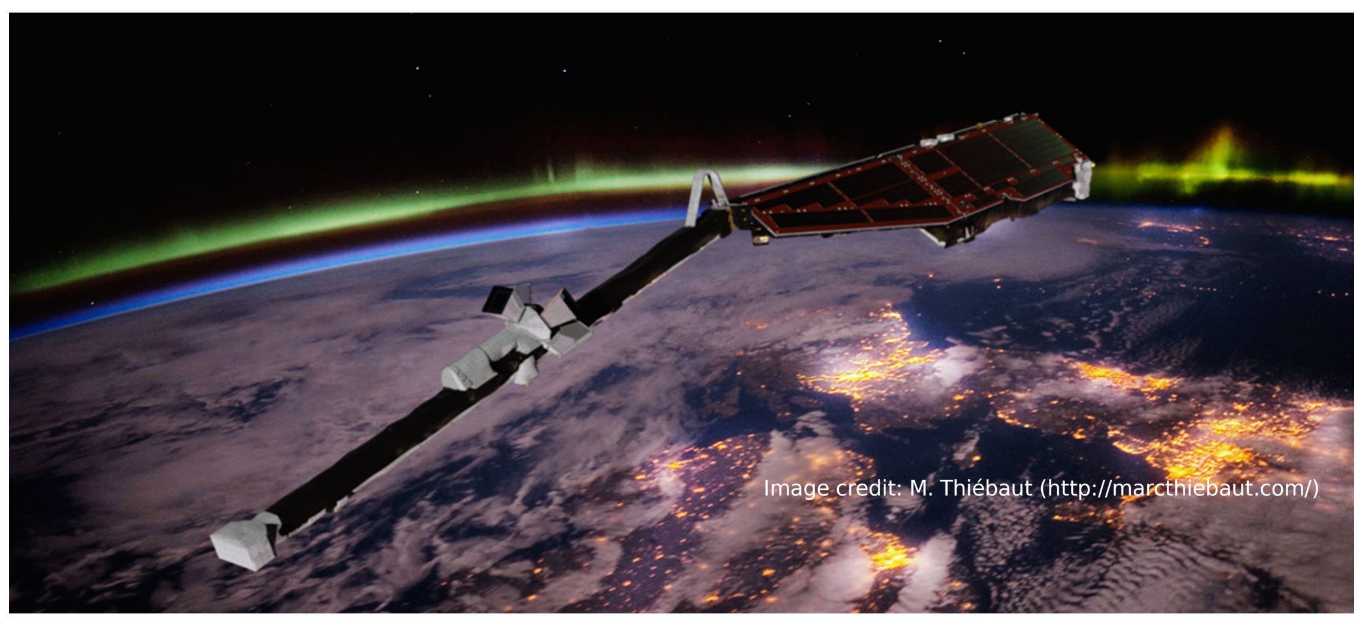
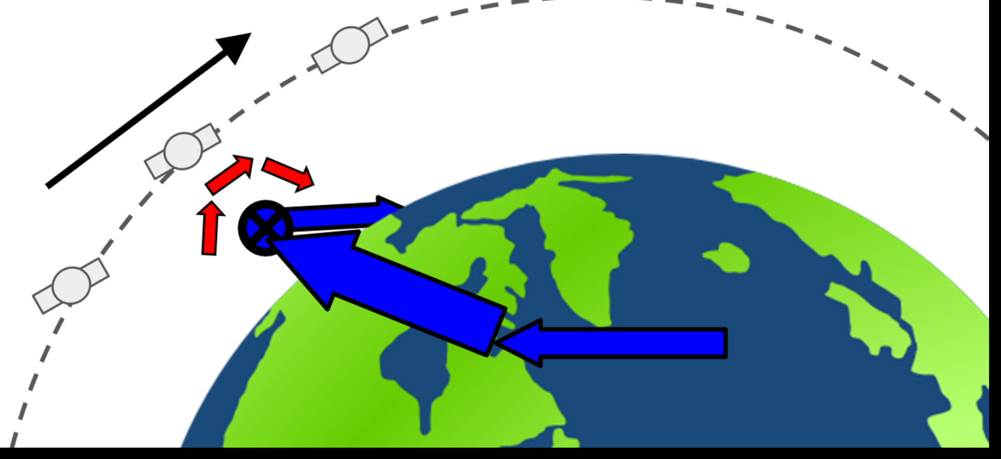


Image credit: M. Thiébaut (http://marcthiebaut.com/)

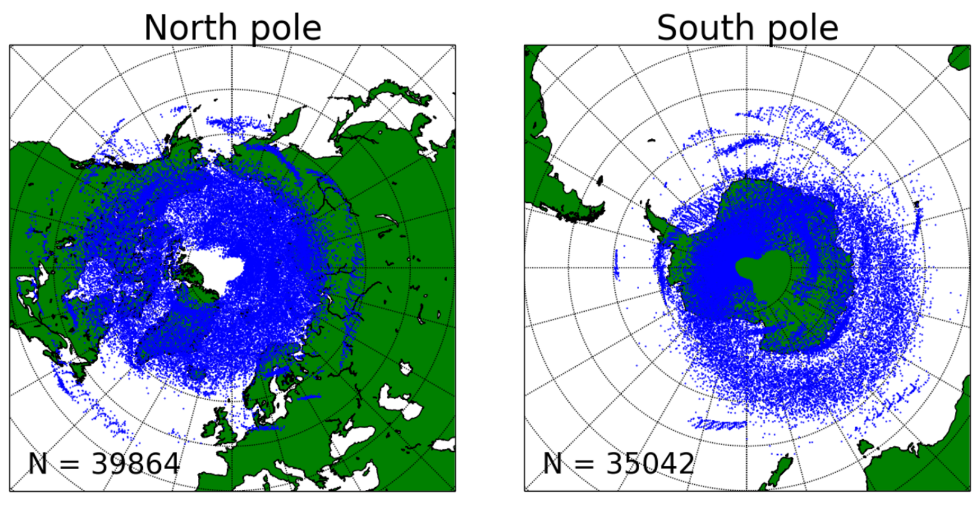
There have been several demonstrations of using satellites to monitor the auroral electrojets: Olsen (1996) using Magsat; Moretto et al. (2002) using Oersted, CHAMP, and SAC-C; Juusola et al. (2009) and Vennerstrom and Moretto (2013) using CHAMP; and Hamilton and Macmillan (2013) using Magsat and CHAMP. The results presented here apply the method of Vennerstrom and Moretto (2013) to data from Swarm.



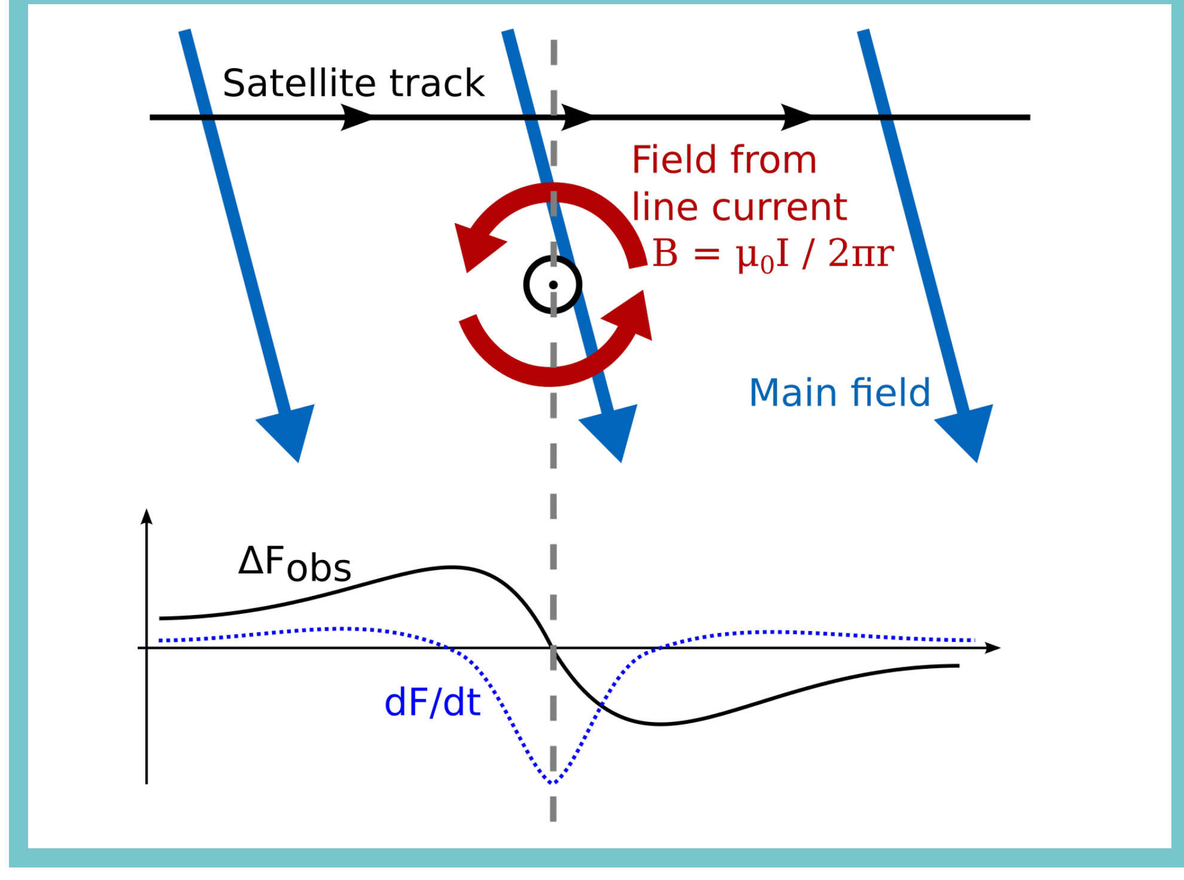
2) Methodology

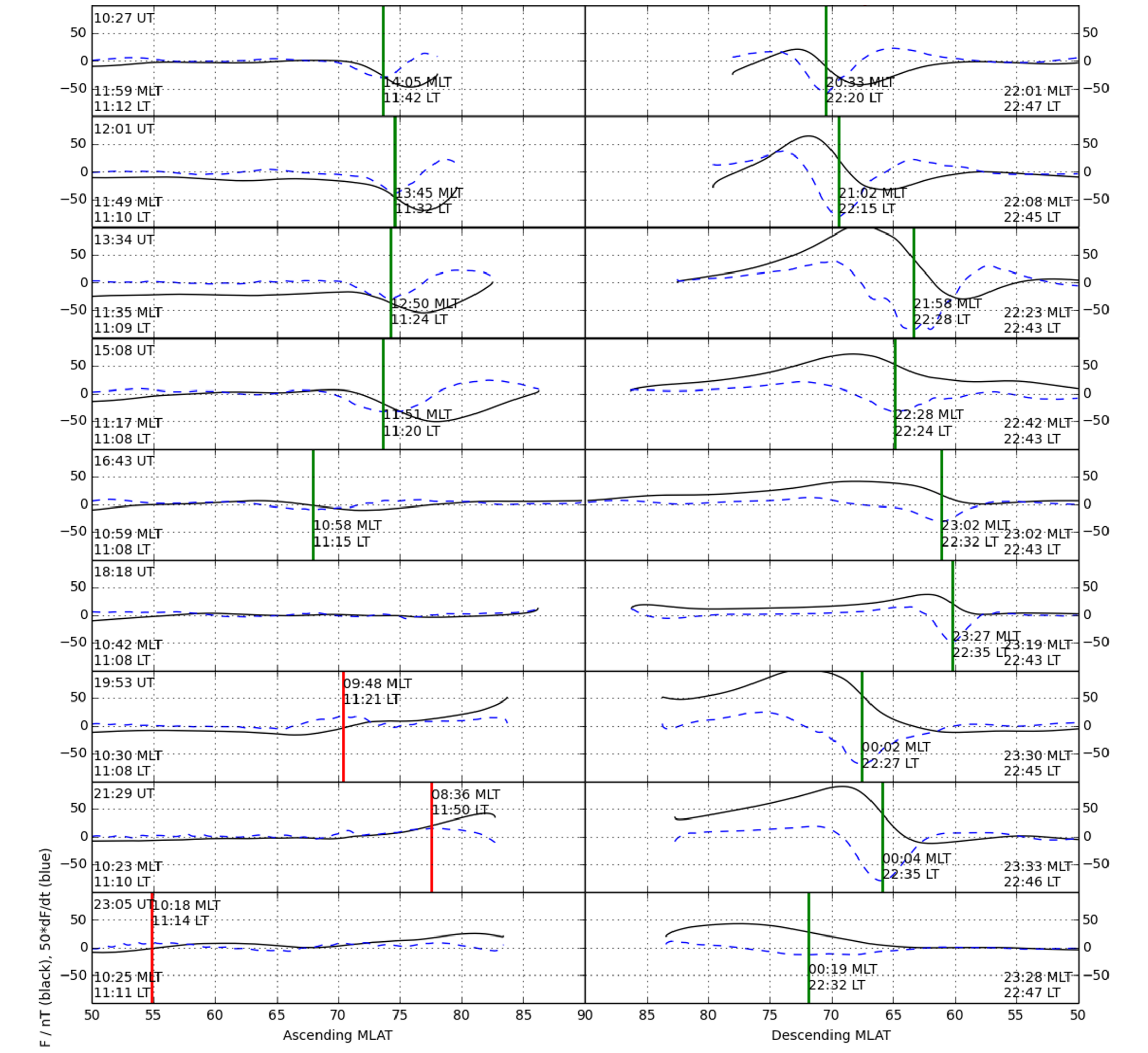
Following the methodology of Vennerstrom and Moretto (2013), we use Swarm A and B scalar magnetic measurements to estimate the magnetic perturbation caused by a model line current placed at 115 km, assuming that the magnetic field component parallel to the main (internal) field is approximated by the magnitude of the total field (i.e. that given by the scalar data). This is valid because the other contributions to the total field are small compared to the main field (see Moretto et al. 2002). By using this approximation, perturbations to the parallel component (i.e. nearly vertical in the polar regions) can be observed in the scalar data.

The procedure is summarised as:
1. Subtract core field model from measured field
2. Partition the time series into consecutive auroral zone passes
3. For each pass, identify the maximum in the gradient of the scalar field, F
4. Estimate the line current that produces this gradient maximum; assign this current and latitude as the auroral electrojet. NB: it only approximates the centre of the system and does not show its extent
5. These detections are collected over many orbits, as shown here in geographic coordinates (each blue dot represents a detection):

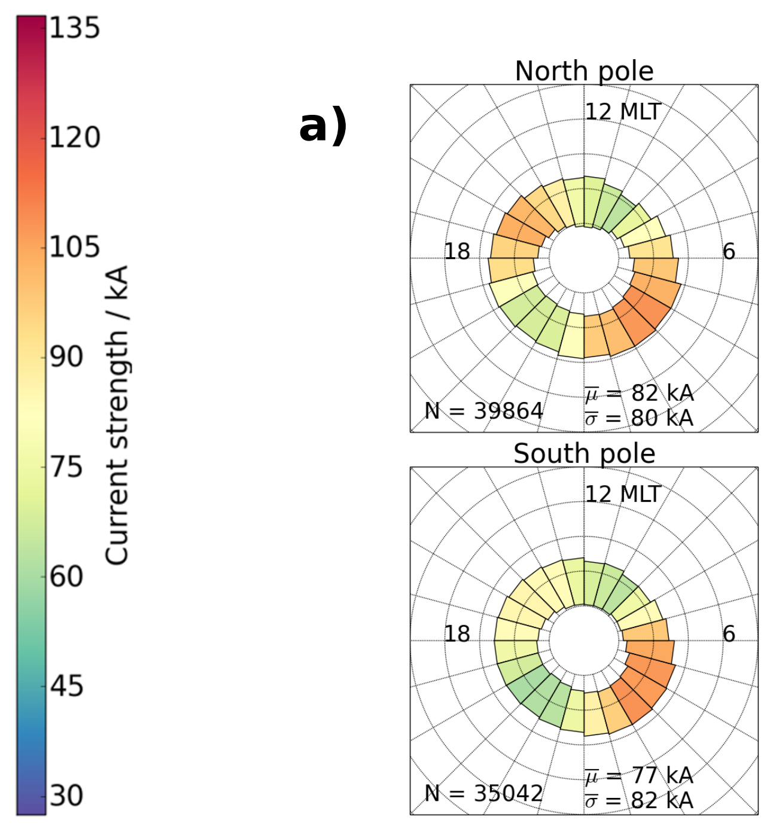


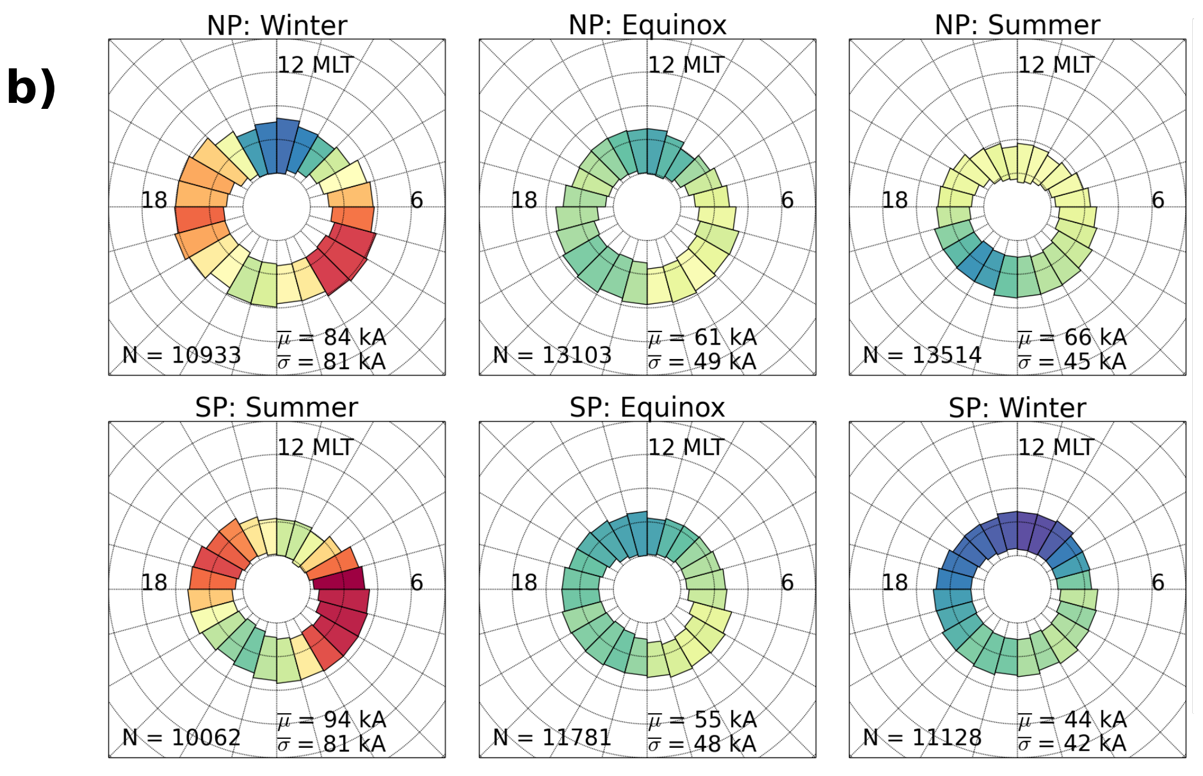
Figures: Below) The perturbation to the scalar magnetic field, F (black solid line), and the resulting peak in its point-to-point differences along the satellite track (approximating dF/dt as the along-track spatial derivative, blue dotted line). **Right)** The signal tracking over consecutive orbits.

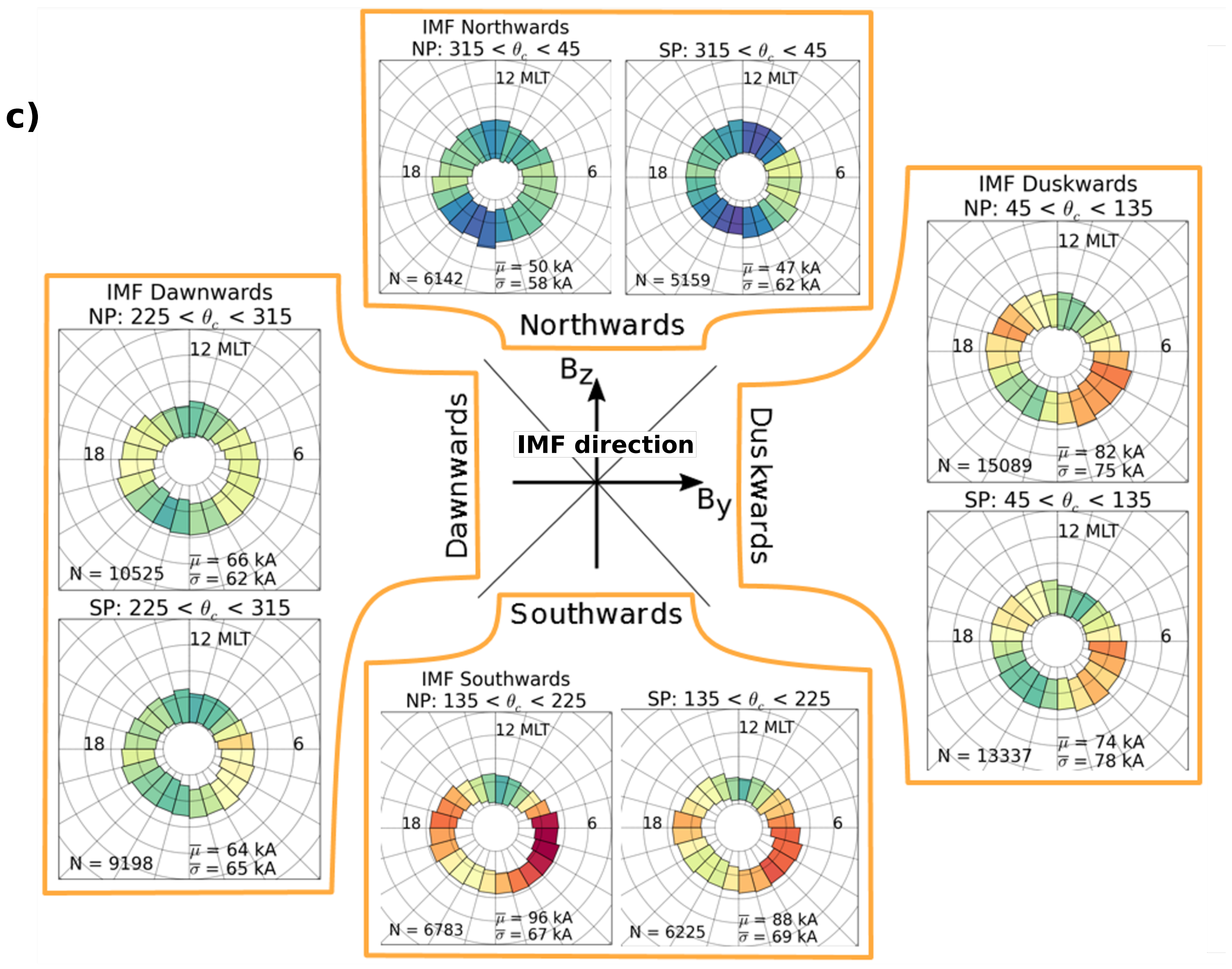




3) Results from Swarm

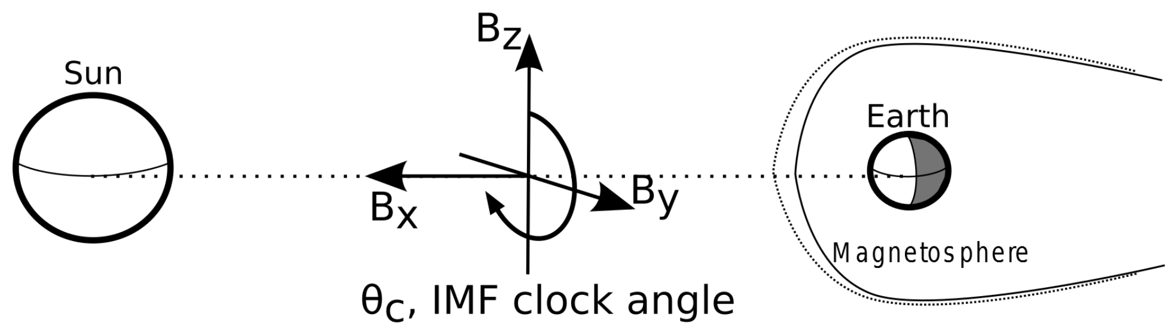




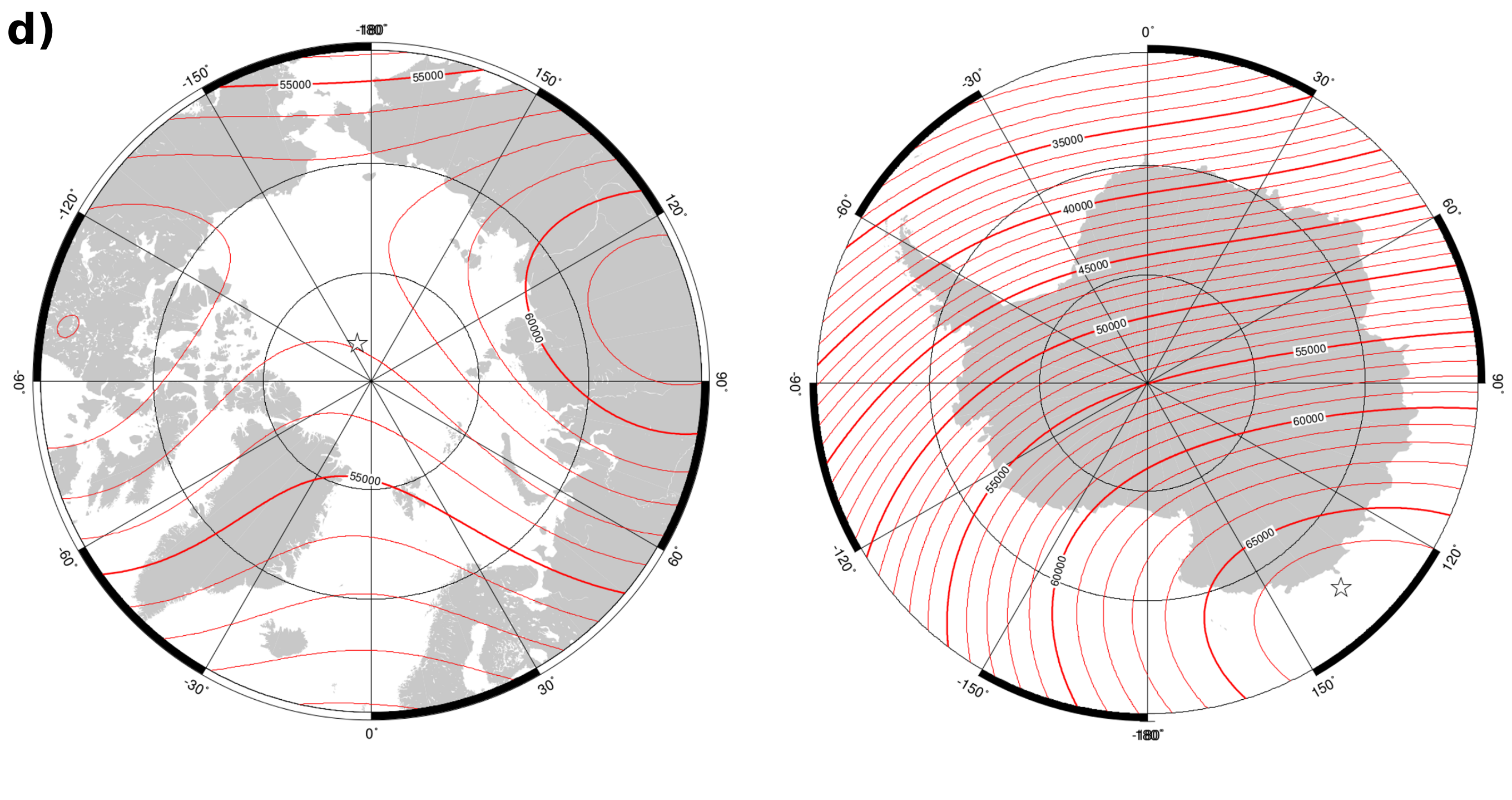


Figures:
(a) Data are collected from two years of Swarm A and B operations. The location, intensity, and variability of the electrojet are depicted, using coordinates of magnetic dipole latitude (MLAT) and magnetic dipole local time (MLT). The data are collected into bins of 1h MLT, and the latitudinal extent of each bin marks marks one standard deviation either side of the mean latitude. The oval demarked thus indicates the spread in the electrojet position; the colours indicate the mean current strength. **(b)** explores the variation with season, and **(c)** with IMF clock angle

(d) WMM2015: The main magnetic field intensity, F, differs between poles (Credit: BGS)



θ_C, IMF clock angle



Key points:
- The oval extends equatorwards and currents increase in strength with increasing activity
- The system can be well ordered by the IMF conditions, with clear increases during southward IMF
- There are stronger currents for IMF-By>0 (duskward) than for By<0 (c.f. Østgaard et al., 2004 ?)
- Hemispheric differences are shown, such as typically weaker currents in the South, except during summer, driven by differences in the main field intensity and inclination

Questions:
- What governs the asymmetric By response and the interhemispheric differences?
- How does the oval centre move?
- Can secular variation be detected in the auroral oval?

References

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